NASA TECHNICAL MEMORANDUM

NASA TM X-1530

NASA TM X-1530

A METHOD FOR THE SURFACE INSTALLATION AND FAIRING OF STATIC-PRESSURE ORIFICES ON A LARGE SUPERSONIC-CRUISE AIRPLANE

by Norman V. Taillon

Flight Research Center
Edwards, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MARCH 1968

NASA TM X-1530

A METHOD FOR THE SURFACE INSTALLATION AND FAIRING OF STATIC-PRESSURE ORIFICES ON A LARGE SUPERSONIC-CRUISE AIRPLANE

By Norman V. Taillon

Flight Research Center
Edwards, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – CFSTI price $3.00

A METHOD FOR THE SURFACE INSTALLATION AND FAIRING OF STATIC-PRESSURE ORIFICES ON A LARGE SUPERSONIC-CRUISE AIRPLANE

By Norman V. Taillon
Flight Research Center

SUMMARY

A method for installing and fairing static-pressure orifices on the wing surface of a supersonic airplane without penetrating the skin is described. Orifice discs were fixed to pressure tubes which were, in turn, attached to the ferrous skin by welded straps. The assembly was faired over with a temperature-resistant aerodynamic smoothing compound hand-milled flush with the orifices. Some deviation from the mold line is inherent in the method; however, analytical estimates indicate that the effect on local aerodynamic pressures is negligible for this installation. The smoothing compound has been found to be operationally suitable at a Mach number of 3.

INTRODUCTION

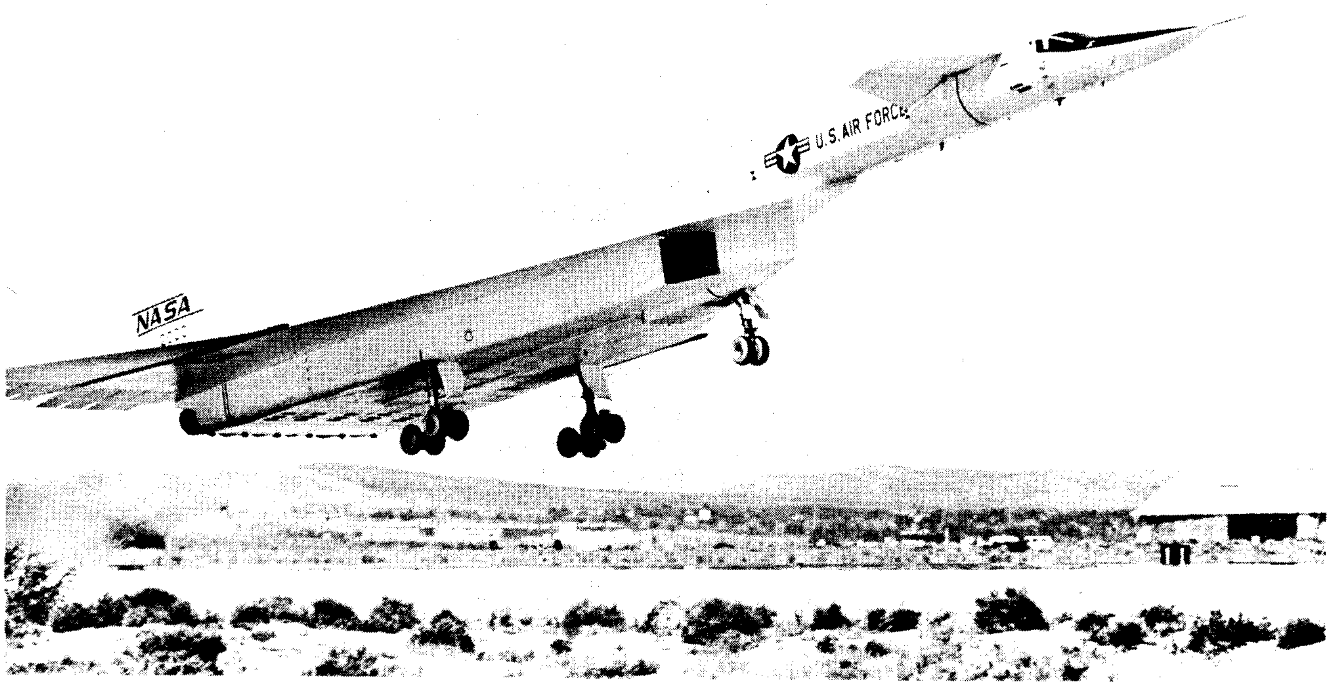
Flush static-pressure orifices in the surface of flight test and research airplanes have, for many years, proved to be highly useful in the evaluation of flow characteristics for further application toward skin-friction, boundary-layer-transition, and pressure-distribution studies. The advent of supersonic-cruise airplanes and vertical or short takeoff configurations with variable-geometry wings, inlets, and ejectors, makes the use of static-pressure orifices an even more valuable tool for analysis of the complex local flows encountered. The large-scale use of honeycomb-sandwich skin and wide dispersion of integral fuel tanks throughout advanced aircraft, however, impose severe restrictions against penetration of the skin for pressure orifices because of the difficulties encountered in sealing and restoration. Similarly, the density of systems hardware and airframe structure, if not the fundamental problem of access, may well discourage internal routing of tubing, particularly when retrofitted to an operational airplane.

Several possible techniques for the installation of flush orifices on the upper wing surface of the XB-70 research airplane were considered. The method selected is described in this paper. This method specifies installing orifices and tubing on the wing surface and fairing them in to minimize the aerodynamic effect on the measured pressures. The method requires no penetration of the skin, allows nearly unlimited selection for the location and spacing of orifice rows, and permits complete removal of the system without extensive disassembly, thereby facilitating a return to the production configuration. Any convenient access to an instrumentation compartment may be utilized.

The fairing material may also be used to smooth out surface irregularities such as thermal expansion joints or welding beads.

BACKGROUND

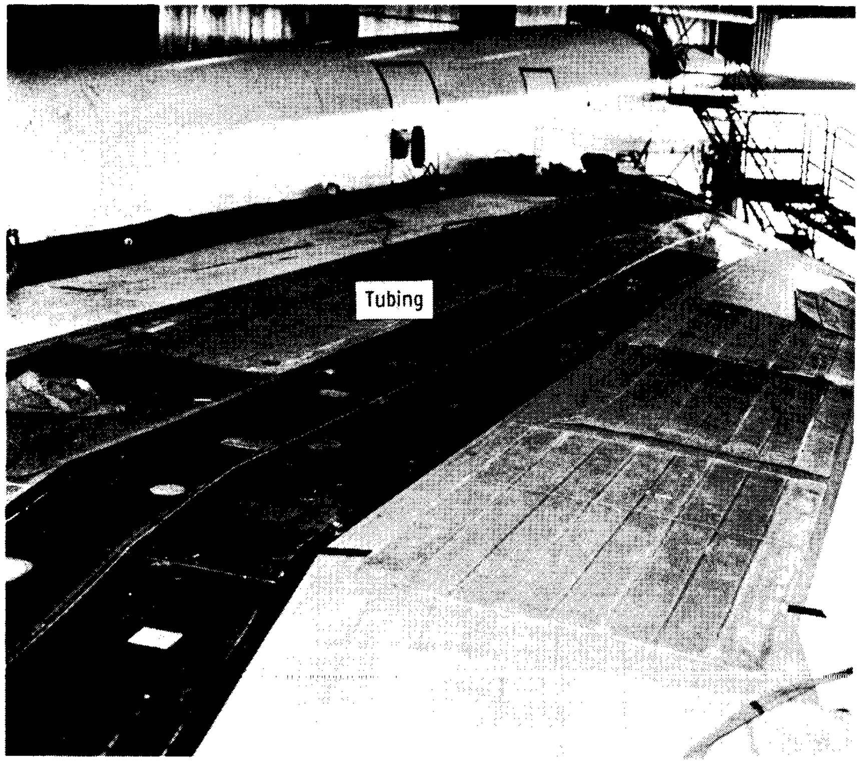
Originally, the third experimental XB-70 airplane was to be fully instrumented during final assembly for NASA skin-friction flight research. Succeeding events, however, led to transfer of the research program to the number 1 airplane (fig. 1) and to retrofit of the instrumentation after initial flight tests had been completed.



E-16694

Figure 1.– The XB–70 research airplane.

As part of the aerodynamic investigation, a row of nine flush static-pressure orifices was required on the upper wing surface of the XB-70. The orifice row was to begin 5 feet (1.5 meters) aft of the leading edge and extend 39 feet (11.9 meters) along the local chord (buttock plane 230), as pictured in figure 2. It was not feasible, however, to route the individual orifice tubes through the wing because that volume was largely occupied by integral fuel tanks. Similarly, the difficulty of sealing precluded penetration of the honeycomb-sandwich wing skin. The manufacturer's previous experience with another aerodynamic smoothing compound suggested the installation of externally mounted hard lines and orifices, and the availability of an access hole into an unused fuel tank immediately forward of the engine bay permitted location of the transducers within the wing.



E–16432

Figure 2.– Upstream view showing the prepared strip and tubing prior to application of the fairing.

METHOD

Tubing Installation

A strip, 36 inches (91.4 centimeters) wide, extending 52 feet (15.9 meters) from the wing leading edge to aft of the wing access hole was outlined with 3-inch (7.6-centimeter) masking tape, and the area thus enclosed was stripped to the bare metal. The metal was lightly sanded to present a better bonding surface for the fairing material that would be applied later.

Orifice discs were silver-soldered tangentially near the ends of 0.093-inch (2.36-millimeter) outer-diameter by 0.067-inch (1.70-millimeter) inner-diameter lengths of stainless-steel tubing as shown in figures 3 and 4. The 0.75-inch- (1.9-centimeter-) diameter discs were machined to thicknesses from 0.060 inch (0.152 centimeter) to 0.120 inch (0.305 centimeter) as needed to maintain the true wing curvature above surface irregularities such as doublers and patches. Each disc was center-punched on top and had a semicircular groove cut across the bottom at the greatest diameter to aid in centering the disc on the tube. In addition, a chord of similar depth was removed from one side of the disc so that overlap on an adjoining tube would not tilt the disc. The projecting short ends of the tubes were plugged airtight with silver solder. Joints in the line were formed of external sleeves silver-soldered at each end to the tubing.

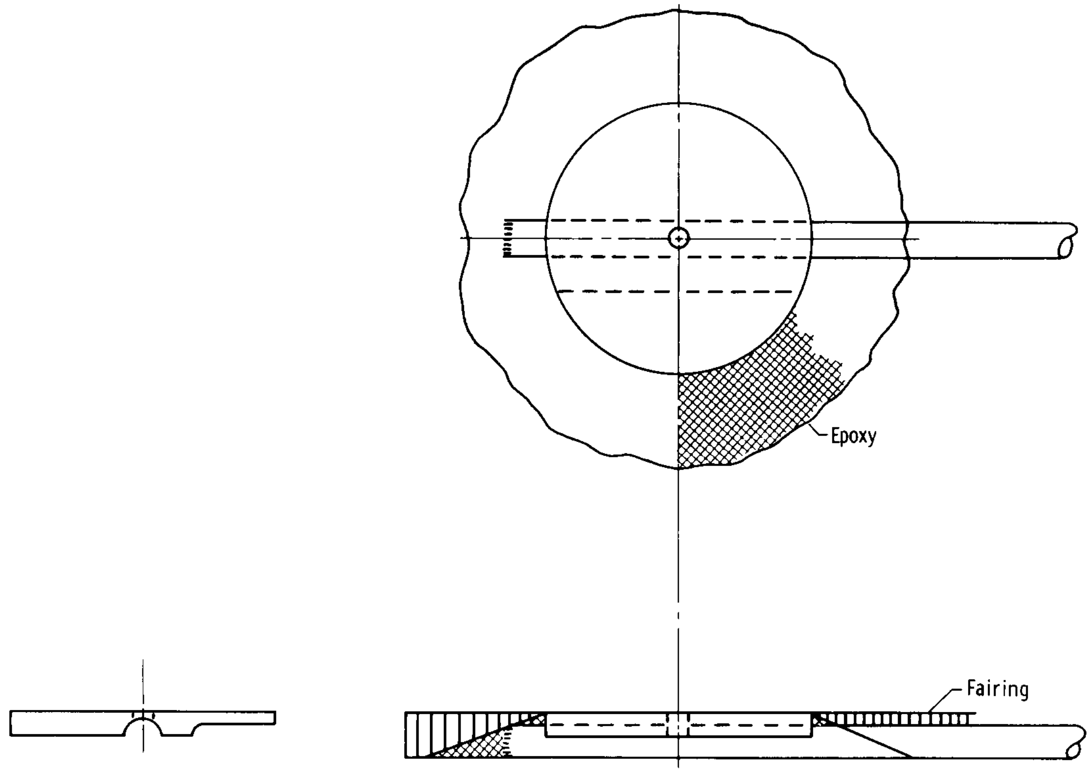
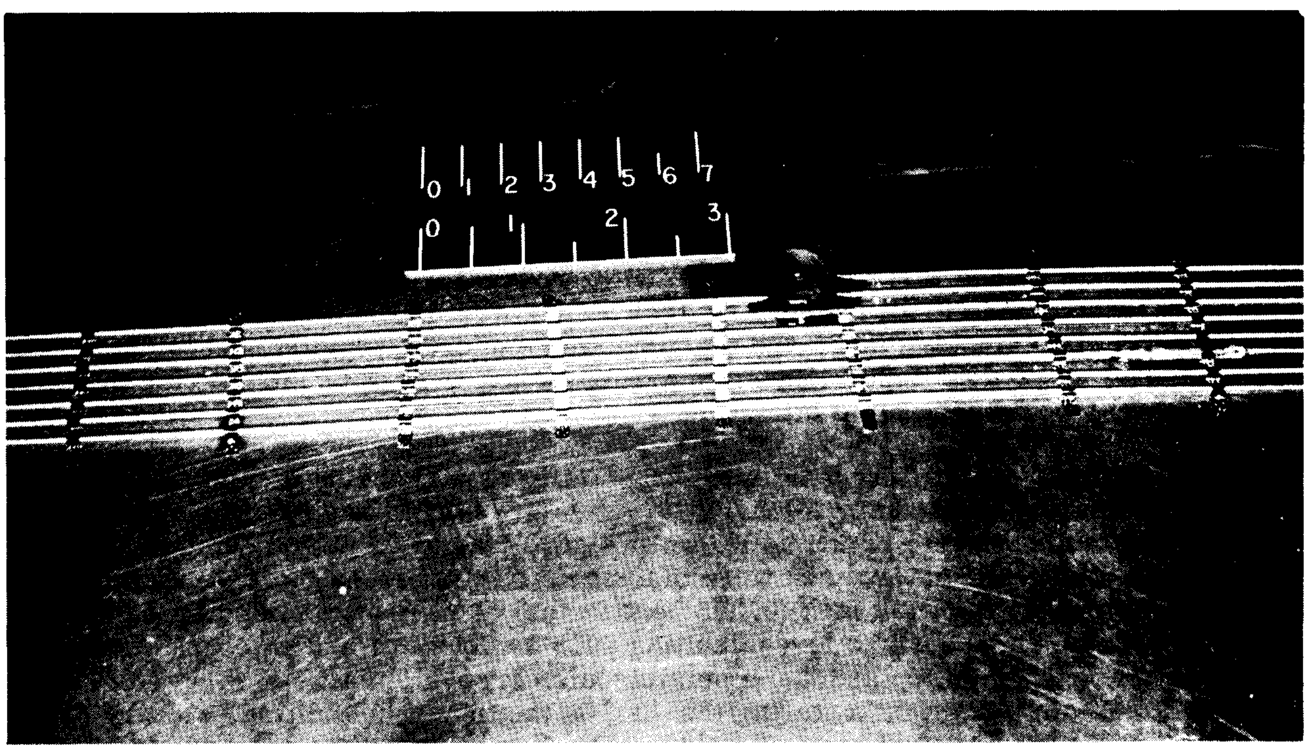


Figure 3.– Sketch of orifice disc. (Not to scale.)



E–16440

Figure 4.– Method of tube attachment. Dimensions in inches (centimeters).

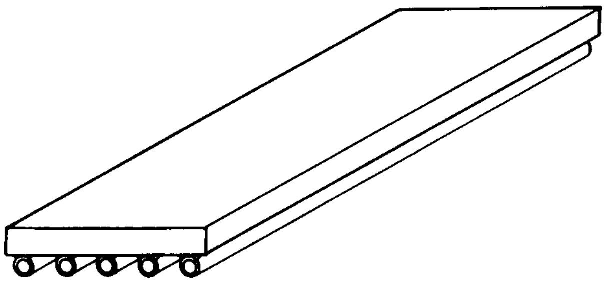
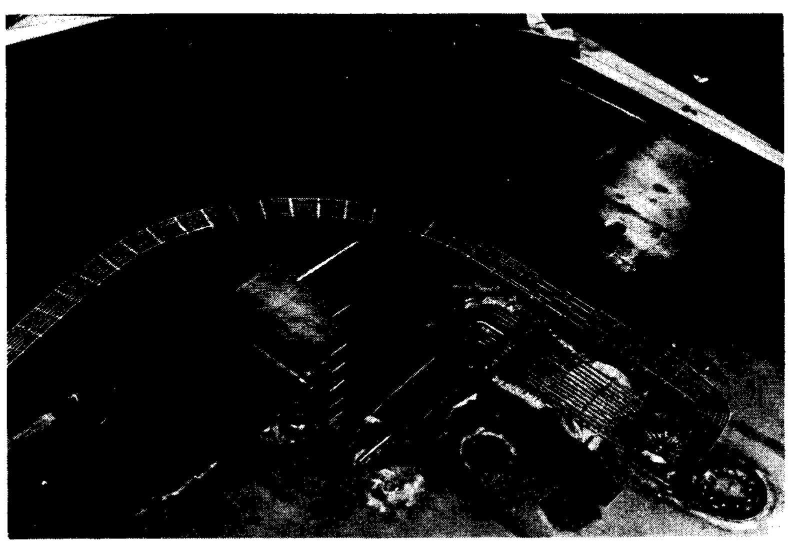


Figure 5.– Tube spacing tool.

The prepared tubes were slightly canted to the centerline of the cleaned strip so that all orifices would be in the same chord plane. Individual tubes were oriented with the orifice disc positioned at the selected station along the chord, while the other end entered the wing access hole. A special spacing tool (fig. 5) was fabricated and used to establish the interval of separation at slightly greater than one tube diameter. The spacing tool was cut to a fraction of its length for use in the curved portion of the tubing complex installed last. The tubes were attached to the 15-7 stainless-steel skin by resistance-tack-welded 0.005-inch- (0.127-millimeter-) thick nichrome straps, 3/16-inch (0.48-centimeter) wide, with 1/2-inch (1.27-centimeter) overlap at each end (fig. 4). The strap was welded to the surface progressively: at one end, then between adjacent tubes, and finally at the other end. A blunted knife blade was used to hold the strap tightly against the tube and skin during the tack welding.

The procedure described was followed until all tubes were fixed in place at about 3-inch (7.6-centimeter) intervals along their entire lengths. Additional straps were then installed between existing straps, reducing the nominal interval to 1 1/2 inches (3.8 centimeters). Orifice ends of the tubes were attached to the skin with large fillets of epoxy cement as shown in figures 3 and 4. Weights were placed on the discs to hold the tubing firmly in contact with the wing surface until the cement had set. After the fairing had been applied and smoothed to final contour, each disc and tube wall was drilled through to 1/16-inch (0.159-centimeter) diameter to form the orifice. Chips were removed from the tubes with high-pressure air, and the hole was left with a sharp edge.

In addition, a boundary-layer rake was bolted to the wing, and the rake tubes were also surface-mounted. The tubes entered the wing through the common access as shown in figure 6.



E–16431

Figure 6.– Tube access to wing interior.

Fairing

Material. – The tubing and orifice discs were faired into the wing surface with a filled, room-temperature-vulcanizing (RTV) silicone rubber developed by North American Rockwell Corporation. Although formally designated as High Temperature Aerodynamic Smoothing Compound, it is more popularly referred to as "Red Thunder." The compound is of putty-like consistency, quite stiff when set, and can be easily contoured. Temperature requirements for the RTV, as approved for the XB-70 program, were established by the manufacturer at -65° F (-53.9° C) and 500° F (260° C) for a minimum period of 200 hours.

Application. – Preparation of the tubing and sanded metal surface for application of the fairing compound consisted of an initial wiping with methyl ethyl ketone followed by a thorough cleaning with trichloroethane. Both tubing and surface were then sprayed with a light coating of a silicone primer compatible with the RTV. Red Thunder was catalyzed in batches of 1000 grams and troweled on the surface and tubing, beginning at the leading edge. The covering was applied in a band about 30 inches (76.2 centimeters) wide, with a crown centered on the orifice row and tapering out to a feather edge at each side (fig. 7). A 1000-gram batch covered about 18 inches (45.72 centimeters) in the chordwise direction. Curing time was approximately 1 hour.

E-16425

Figure 7.– Partially covered tubing.

The coating level was kept higher than the orifice discs to insure a supply of extra material for removal in the smoothing process. After application, the RTV was continually troweled until it was firm enough that no flow could be discerned. The few air bubbles that arose during the troweling process were burst with a pointed tool. Reference marks were carefully placed at the side of the fairing strip to aid in locating the orifice discs after they were covered with Red Thunder. The marks were not needed, however, since shrinkage in the cured material clearly revealed the location of the discs. Figure 8 shows the fairing after the application had been completed. Trowel marks, waviness, the foremost orifice disc, and its tube may be detected in the photograph.

E–16427

Figure 8.– Rough fairing completed.
View from leading edge looking aft.

Smoothing. – After the fairing had completely cured, the material was planed, filed, and sanded flush with the orifice discs, finishing with 180-grit sandpaper (fig. 9). The

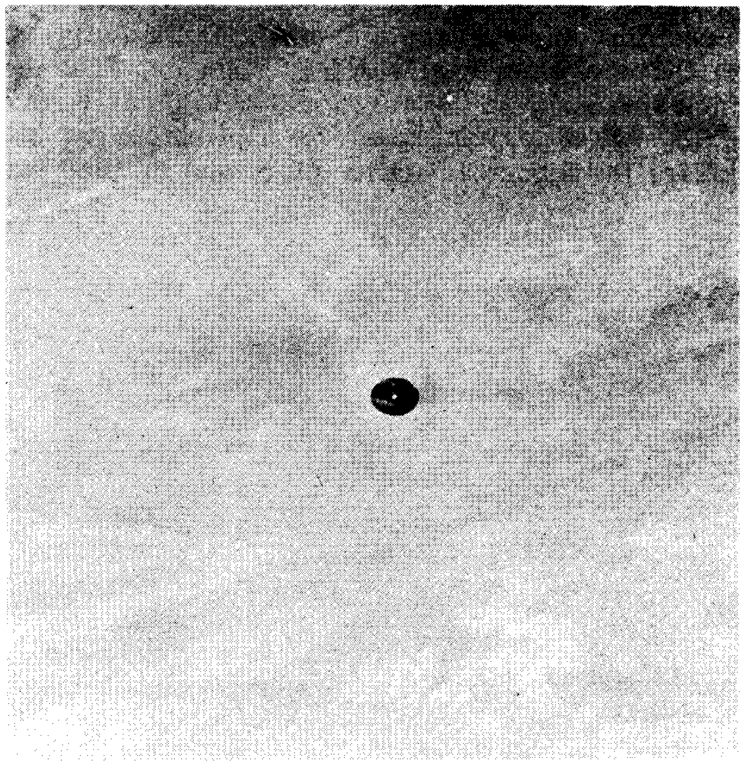
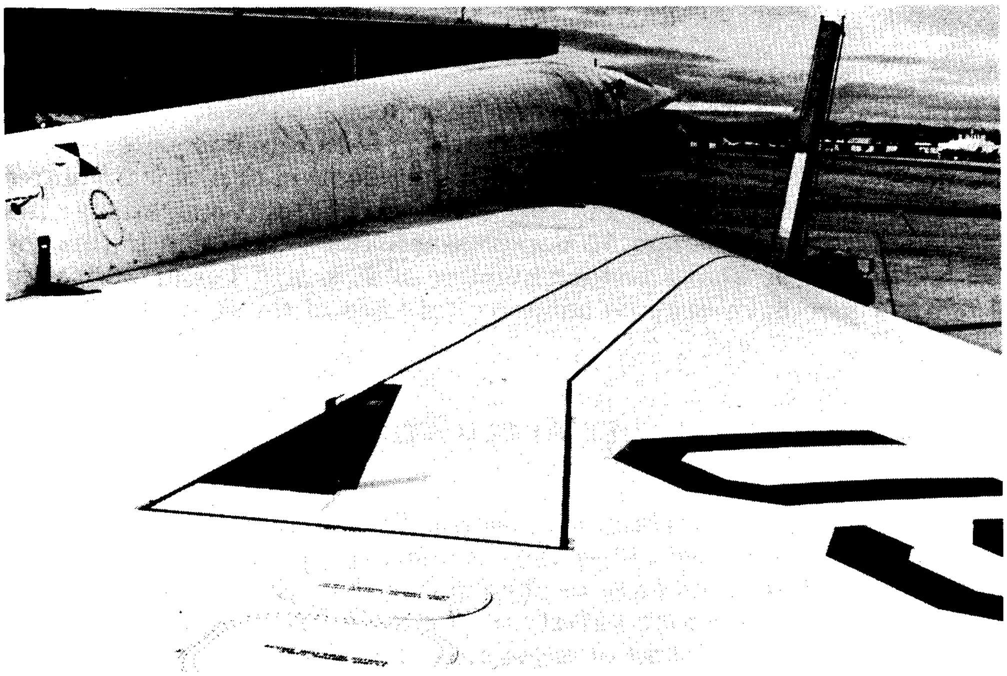


Figure 9.– Fairing smoothed flush with orifice disc. E–16680

wing upper surface is without curvature for the greater part of its chord, so that a long straightedge could be used to insure flatness. Near the cambered leading edge, the contour was established by sight, using adjacent orifice discs as reference points and a shorter straightedge to detect waviness. The maximum gap below a straightedge, as determined with a feeler gage, was about 0.004 inch (0.10 millimeter).

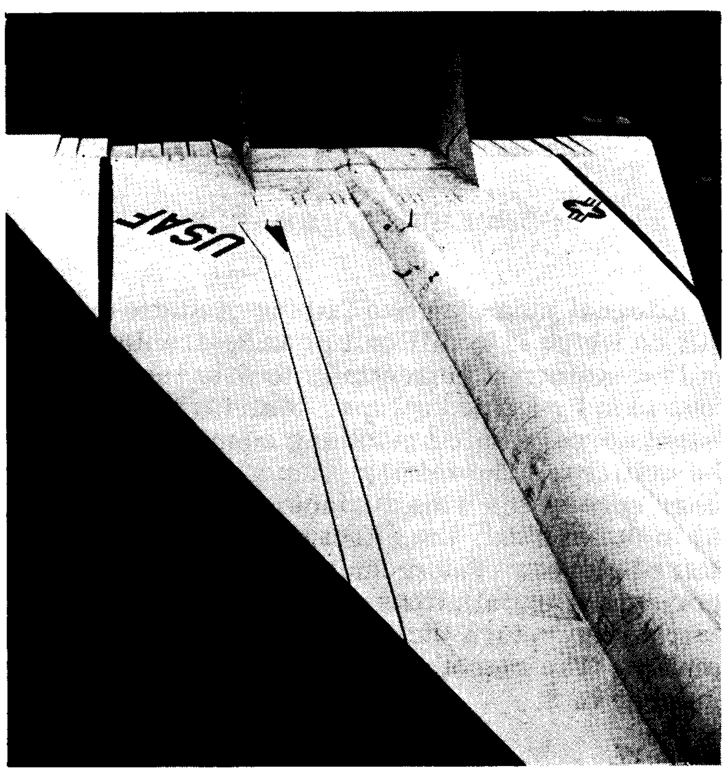
It is estimated that the faired surface is more accurate, aerodynamically, than the manufactured surface, considering the presence of doublers and welding beads on the latter. Low spots and voids in the smoothed fairing were built up with further applications of Red Thunder without adhesive difficulty, and some orifice discs that had tilted slightly were filed flush with the surrounding material. The maximum local thickness of the fairing varied from about 0.122 inch (0.310 centimeter) to 0.182 inch (0.462 centimeter). The minor deviation from the airfoil cross section, together with the shallow lateral slope of the fairing, is believed to result in a negligible effect on the measured pressures.

Finishing. – The smoothed Red Thunder was cleaned with a mild detergent and sprayed with White Thermal Control Coating, a silicone-base paint manufactured by Rinshed-Mason Company, Detroit, Mich. When dry, the paint was brought to a final finish by wet-sanding with 400-grit open-mesh abrasive sheets. The faired area was then outlined with a red strip, and "No Step" stencils were applied at intervals along the strip to protect the finish against scuffing (figs. 10(a) and 10(b)).



E–16567

(a) View looking forward.



E–16563

(b) View looking aft.

Figure 10.– Finished wing surface.

OPERATIONAL EXPERIENCE

Flight experience with Red Thunder has been accumulated on two XB-70 airplanes. Some local loss of adhesion of the RTV to the wing skin was encountered during initial flight tests; however, this was corrected with the adoption of a new primer that was determined to be more compatible with the compound. Total operational time with the revised preparation method is now 75 hours 30 minutes. Included in this total are 14 hours 35 minutes at or above a Mach number of 2.5, and 1 hour 38 minutes at a Mach number of 3.0. There have been no adhesive failures of the Red Thunder during this time.

OTHER APPLICATIONS

Although the technique described was confined to the installation of flush orifices on the wing of a large supersonic airplane, it could be adapted to a variety of temporary or semipermanent installations such as thermocouples, strain gages, and hydraulic or fluidic lines for the even wider variety of purposes that they might suggest. It should be noted that the coefficient of expansion of Red Thunder was determined by laboratory test to be very close to that of stainless steel but might differ greatly from that of another skin metal. This factor would have to be taken into consideration where substantial heating effects were anticipated. Epoxy cement might prove to be a useful alternate for attaching tubing where the skin material precluded welding. Red Thunder is particularly useful as a fairing material because of its stiffness, which makes it easily workable with readily available tools. Some local deviation from the manufactured airfoil cross section or fuselage mold line is inherent in the method; however, the effect on local pressures may be minimized by recourse to gently faired slopes.

CONCLUDING REMARKS

A method for the external mounting and fairing of static-pressure orifices has been developed for aircraft on which it is difficult or undesirable to penetrate the skin. Orifice discs were silver-soldered tangentially to pressure tubes that were, in turn, attached to the ferrous skin by welded straps. Fairing was accomplished by means of a temperature-resistant aerodynamic smoothing compound spread over the tubes and worked flush with the orifices. The fairing strip was tapered from a crown at the orifice row to a feather edge at the wing surface. Although some deviation from the mold line is inherent in the method, the effect on local pressures can be minimized by recourse to gently faired slopes. The technique is readily adaptable to a variety of temporary or semipermanent installations for research or prototype development airplanes when it is desirable to return the airplane to production configuration with a minimum of disassembly. The smoothing compound was found to be operationally suitable at a Mach number of 3.

Flight Research Center,
National Aeronautics and Space Administration,
Edwards, Calif., December 8, 1967,
732-01-00-02-24.

NASA-Langley, 1968 — 1 H-505